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SUBMISSION OF VERIFIED TRANSLATION OF FOREIGN PRIORITY DOCUMENT

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August 3, 2004

Sir:

Applicants respectfully submit the enclosed verified English-language translation of the foreign priority document. Applicants respectfully assert that a claim to foreign priority has been perfected. In the event that any fees are due with respect to this paper, please charge our Deposit Account No. 01-2300, **referencing attorney docket no.: 106145-00028**.

Respectfully submitted,

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VERIFICATION OF TRANSLATION

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Signature of translator: A. Yoshida

Akishige Yoshida

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[Name of Document] Specification

[Title of the Invention] Fuel Cell System

[What is Claimed is]

[Claim 1]

A fuel cell system comprising:

a fuel cell in which fuel gas and oxidant gas are supplied to generate power;

an evaporator which evaporates raw fuel liquid by combustion heat obtained by combusting exhaust gas exhausted from said fuel cell to provide raw fuel gas; and

a reformer which reforms the raw fuel gas supplied from said evaporator

to provide said fuel gas;

said fuel cell system further comprising:

an air introduction member which introduces air for use in the reforming reaction in said reformer; and

the air introduced from said air introduction member being supplied from said evaporator to said reformer.

[Claim 2]

The fuel cell system according to claim 1, where said air introduction member introduces the air at the time of starting said fuel cell system.

[Claim 3]

The fuel cell system according to claim 2, wherein a second air introduction member is configured so as to introduce the air into the evaporator in an amount larger than that of said air introduction member.

[Claim 4]

The fuel cell system according to claim 1, wherein before the raw fuel gas is introduced into the evaporator and after the air introduction from the air introduction member is started, the raw fuel liquid is supplied to the evaporator when at least one of an evaporator temperature signal based on a temperature of the evaporator and a reforming catalyst temperature signal based on a temperature of the reforming catalyst exceeds a prescribed value.

[Claim 5]

The fuel cell system according to any of claims 2 and 3, wherein before the raw fuel gas is introduced into the evaporator and after the air introduction from the second air introduction member is started, the air introduction from the second air introduction member is stopped when at least one of a evaporator temperature signal based on a temperature of the

evaporator and a reforming catalyst temperature signal based on a temperature of the reforming catalyst exceeds a prescribed value, and the raw fuel liquid is supplied to the evaporator.

[0001]

[Field of the Invention]

The present invention relates to a reformation type fuel cell system, which reforms a fuel such as methanol into a hydrogen-enriched fuel gas and takes it, and particularly, to a fuel cell system suitable as a power source for an electric vehicle.

[0002]

[Prior Art]

In recent years, various electric vehicles, which have a driving motor mounted thereon instead of an engine, have been developed. As one of such types of vehicles, development of a vehicle (hereinafter referred to as "fuel cell electric vehicle") having a fuel cell system as a power source for the driving motor mounted thereon has been sharply made. A so-called reformation type fuel cell system has been known as one of such fuel cell systems.

[0003]

An example of the reformation type fuel cell system for use in the fuel cell electric vehicle will be described with reference to Fig. 7. A fuel cell system 50 depicted on Fig. 7 has a fuel cell 51, in which a hydrogen-enriched gas is supplied to an anode side thereof and air serving as an oxidant gas is supplied to a cathode side thereof to thereby generate electric power. The fuel cell system 50 also has an evaporator 52 which evaporates raw fuel liquid such as water/methanol mixed liquid to form raw fuel gas. To the evaporator 52 is connected a storage tank T for the water/methanol mixed liquid via a pump P,

and the raw fuel liquid comprising the water/methanol mixed liquid is supplied to the evaporator 52 by an actuation of the pump P. The raw fuel gas obtained by the evaporation of the raw fuel liquid by means of the evaporator 52 is supplied to a reformer 53. In the reformer 53 the raw fuel gas undergoes a catalytic reforming reaction such as an automatic thermal reaction to produce a hydrogen-enriched fuel gas. The fuel gas produced in the reformer 53 is supplied to a CO remover 54 at which a carbon monoxide by-product produced in the course of the reforming reaction, which is harmful for the fuel cell 51, is removed. The fuel gas from which carbon monoxide is removed by means of the CO remover 54 is then supplied to the anode side of the fuel cell 51. The fuel cell system 50 also has an air compressor 55, and by means of the air compressor 55, the air as the oxidant gas is supplied to the cathode side of the fuel cell 51. The air compressor 55 supplies the air as reforming air required for the reforming reaction (hereinafter referred to as "reforming air") to the reformer 53.

[0004]

In addition, when the fuel cell electric vehicle having the fuel cell system 50 mounted thereon, which has been stopped, is started, the evaporator 52, the reformer 53, and the like are usually cooled. For this reason, in order to exhibit prescribed performances possessed by the evaporator 52 and the reformer 53, a certain degree of heat is required for heating them. For this reason, in the conventional fuel cell system 50a are provided a combustion starting burner 56 for heating the evaporator 52 and a starting combustion burner 57 for heating the reformer 53. And after a catalyst layer of the evaporator 52 and a reforming catalyst of the reformer 53 are heated up to prescribed temperatures, respectively, by means of the combustion burners 56

and 57 for starting, the raw fuel liquid is supplied and the reforming air is supplied in the conventional fuel cell system 50.

[0005]

[Problems to be Solved]

Meanwhile, because the reforming air is directly introduced into the reformer 53 in the conventional fuel cell system 50, in some cases, the reforming air is not introduced into the reformer 53 in a uniform manner. In this case, a density difference of the reforming air occurs in the reformer 53, a mixture of the raw fuel gas and the reforming air becomes worse, there is a possibility of causing uneven temperatures on surfaces of the reforming catalyst provided within the reformer 53. To be more precise, the temperature of the reforming catalyst becomes higher at a portion where the reforming air is concentrated, while the temperature of the reforming catalyst becomes lower at a portion where the reforming catalyst is diluted. Specifically, the oxidation represented by a formula (1), which is an exothermic reaction is accelerated on the portion where the reforming air is concentrated, and due to the heat generated at this time, the temperature of the reforming catalyst is increased.

$$CH_3OH + 3/2O_2 \rightarrow 2H_2O + CO_2 \quad (1)$$

On the other hand, a steam reforming reaction represented by a following formula (2), which is an endothermic reaction, is promoted on the portion where the reforming air is diluted, and the temperature of the reforming catalyst is decreased due to the endothermic reaction.

$$CH_3OH + H_2O \rightarrow 3\ H_2 + CO_2 \qquad (2)$$

Here, in Fig. 8 is shown a relationship between a concentration of carbon monoxide in fuel gas and a temperature of a reforming catalyst. If the

temperature of the reforming catalyst is low, an amount of total hydrocarbons (THC) becomes high, meaning that the raw fuel gas is passed through with no or insufficient reformation, and the CO concentration results in becoming low. On the other hand, the THC is decreased according to an increase of the temperature of the reforming catalyst and the CO concentration has a tendency to be increased. Consequently, with such uneven temperatures of the surfaces of the reforming catalyst, there arises a problem that: the raw fuel gas is passed through with no or insufficient reformation on the portion where the temperature of the reforming catalyst is low, and unreformed gas becomes much; whereas the CO concentration becomes high on the portion where the temperature of the reforming catalyst is high. If an amount of the unreformed gas is increased, no sufficient amount of hydrogen can be obtained, and thereby it is thought that a power generation in the fuel cell 51 has a trouble. On the other hand, if the CO concentration is high, there is a problem such as a fear of poisoning the fuel cell 51 with CO.

[0006]

In order to solve such the problem, it can be thought that as shown in an ideal line of Fig. 7 a mixer 58 for mixing the raw fuel gas with the reforming air is separately disposed for a purpose of homogenizing the temperature distribution over the reforming catalyst. However, if such the mixer 58 is disposed, the fuel cell system 50 becomes large-scale, or a pressure loss of the total system becomes large, leading to poor system efficiency.

[0007]

On the other hand, at the time of starting the conventional fuel cell system 50, two starting combustion burners, i.e., the starting combustion burner 56 for warming up the evaporator 52 and the starting combustion

burner 57 for warming up the reformer 53, have been utilized. However, the use of many starting combustion burners as described above also leads to enlarge the size of the system and equipment, causing a problem of unsuitability for use in the fuel cell system mounted in a vehicle.

[0008]

Consequently, a problem of the present invention exists in adequately mixing the fuel gas and the reforming air in the reformer and swiftly operating the evaporator and the reformer at the time of starting without totally enlarging the fuel cell system.

[0009]

[Means for Solving the Problems]

An invention according to claim 1 of the present invention for solving the problem is a fuel cell system that comprises a fuel cell, where fuel gas and oxidant gas are supplied, for generating power; an evaporator for evaporating raw fuel liquid by combustion heat obtained by burning exhaust gas exhausted from the fuel cell, and thereby making raw fuel gas; a reformer for reforming the raw fuel gas supplied from the evaporator, and thereby making the fuel gas; and an air introduction member for introducing air for use in reforming reaction (reforming air) in the reformer; wherein the air introduced from the air introduction member is supplied from the evaporator to there reformer.

[0010]

In the invention according to claim1, the air used for the reforming reaction in the reformer is designed to be introduced into the evaporator. Thus, because the air used for the reforming reaction is mixed with the fuel cell in a piping that communicates the evaporator with the reformer, the fuel gas and the reforming air result in being mixed in a sufficiently uniform

manner. As a result, there is no uneven temperature of surfaces of a reforming catalyst, making it possible to prevent the fuel gas within the reformer from remaining unreformed and to prevent a CO concentration from being increased. Furthermore, because the reforming air is well mixed with the fuel gas and thus no additional device such as a mixer is required to be disposed, the fuel cell system is not enlarged as a whole.

Furthermore, according to the fuel cell system of the present invention, the air can be previously introduced into the evaporator prior to the supply of the raw fuel liquid at the time of starting the fuel cell system. The use of the air as a thermal medium makes it possible to rapidly warm up the evaporator. The air used for warming up the evaporator is supplied to the reformer in a state as it is hot. As a result, because the temperature of the reforming catalyst can be increased through the hot air, there is no need for disposing any starting combustion burner, promoting miniaturization of the fuel cell system as a whole.

[0011]

The invention according to claim 2 is the fuel cell system of claim 1 that comprises a second air introduction member, which introduces air into the evaporator at the time of starting the fuel cell system.

[0012]

Now, comparing the introduction of the air into the evaporator at the time of staring the fuel cell system with that at the time of a normal operation except for the starting in introducing the air into the evaporator, a much larger amount of the air is required at the starting, because a large amount of the air serving as the thermal medium is required for rapid warming-up.

In contrast, in the normal operation, only a small amount of the air is

required (for the reformation), while a fine adjustment of the amount of the air is required, depending on an operating situation of the fuel cell system. Consequently, it is thought to accompany difficulty in introducing a large amount of the air required for nothing but the starting with using the air introduction member for introducing the air in the normal operation, taking the configuration of the air introduction member into consideration. For this reason, in the invention according to claim 2, the second air introduction member for introducing the air is separately disposed. When the fuel cell system is started, the air is introduced both from the air introduction member and the second air introduction member, whereby a large amount of the air required for the starting can be appropriately introduced.

[0013]

The invention according to claim 3 is the fuel cell system of claim 2, wherein the second air introduction member is designed to introduce a larger amount of the air into the evaporator than the air introduction member.

[0014]

The invention according to claim 3 can introduce the air into the evaporator from the second air introduction member at starting the fuel cell system and from the air introduction member in the normal operation. Accordingly, the air introduction members including second one may be simply configured, and each control thereof becomes easy.

[0015]

The invention according to claim 4 is the fuel cell system of claim 1 that supplies the liquid raw fuel to the evaporator when at least one of a evaporator temperature signal based on a temperature of the evaporator and a reforming catalyst temperature based on a temperature of a reforming catalyst exceeds a

prescribed value.

[0016]

The invention according to claim 5 is the fuel cell system of any of claims 2 and 3 that stops air introduction from the second air introduction member, supplies the raw fuel liquid to the evaporator, and starts the air introduction from the air introduction member before the raw fuel gas is introduced into the evaporator and after the air introduction from the second air introduction member is started, when at least one of an evaporator temperature signal based on a temperature of the evaporator and a reforming catalyst temperature signal based on a temperature of the reforming catalyst exceeds a prescribed value.

[0017]

The invention according to claims 4 and 5 starts to supply the raw fuel liquid to the evaporator when at least one of the evaporator temperature signal based on the temperature of the evaporator and the reforming catalyst temperature signal based on the temperature of the reforming catalyst exceeds a prescribed value. For this reason, after a state for reforming fuel in the fuel cell system becomes ready, the invention can supply the raw fuel liquid to the evaporator and surely start production of fuel gas.

[0018]

[Description of the Preferred Embodiments]

Referring to drawings, embodiments of the present invention will now be described specifically.

Fig. 1 shows a configuration drawing of a fuel cell system according to the present invention. As shown in Fig. 1, the fuel cell system FCS according to the present invention is mounted on a fuel cell electric vehicle, and

possesses a fuel cell 1, an evaporator 2, a reformer 3, a CO remover 4, an air compressor 5, and a starting combustion burner 6.

[0019]

The fuel cell 1 has a configuration, in which a plurality of cells are laminated, and is divided into an anode side, into which fuel gas is supplied, and a cathode side, into which air as oxidant gas is supplied, by means of these cells. From the fuel gas supplied to the anode side and the oxidant gas supplied to the cathode side, electricity is generated in each cell.

[0020]

The evaporator 2 comprises an evaporator body 11, a catalytic combustor 12, a raw fuel-injecting apparatus 13, and an air introduction member 14. To the raw fuel-injecting apparatus 13 is connected a storage tank T (hereinafter simply referred to as "tank") for water/methanol mixed liquid in which the raw fuel liquid such as the water/methanol mixed liquid is stored. The raw fuel liquid is supplied from the tank T via a pump P to the raw fuel-injecting apparatus 13. The raw fuel liquid supplied to the raw fuel-injecting apparatus 13 is injected at and supplied to the evaporator body 11. At this time, a flow amount of the raw fuel liquid supplied to the evaporator body 11 is regulated by an injection amount injected by the raw fuel-injecting apparatus 13. In addition, the catalytic combustor 12 is disposed at a lower portion of the evaporator body 11. Off gas, which is an exhaust gas exhausted from the fuel cell 1, is introduced into the catalytic combustor 12, at which the off gas is combusted to produce heat. Due to the heat thus produced in the catalytic combustor 12, the raw fuel liquid within the evaporator body 11 is evaporated.

[0021]

The evaporator 2, for example, has a configuration shown in Fig. 2.

As shown in Fig. 2, an evaporation chamber 11A which evaporates the raw fuel liquid into the raw fuel gas is formed within the evaporator body 11. A lot of U-shaped thermal medium tubes 11B, 11B, ... within which combustion gas serving as a high temperature medium flows, are provided within the evaporation chamber 11A. On the other hand, the raw fuel liquid is injected in the evaporation chamber 11A from the raw fuel-injecting apparatus 13 placed on an upper portion of the evaporation chamber 11A. The combustion gas flowing within the thermal medium tubes 11B, 11B, ... renders the raw fuel liquid to heat to thereby evaporate the raw fuel liquid.

[0022]

The catalytic combustor 12 is disposed on a lower portion of the evaporator body 11. On the catalytic combustor 12 is formed an inlet passage 12A into which the off gas, which is heated to become the combustion gas, flows, and a catalyst layer 12B is provided on a downstream of the inlet passage 12A. A honeycomb shaped carrier having a metallic catalyst component carried thereon makes up the catalyst layer 12B, and the off gas is combusted due to catalytic reaction to produce combustion gas.

[0023]

On a downstream of the catalyst layer 12B, an outlet passage 12C is formed by means of a diaphragm 12D, and the combustion gas passes through the outlet passage 12C. The catalyst layer 12B and the thermal medium tubes 11B, 11B, ... in the evaporator body 11 are communicated with each other via the outlet passage 12C formed by the diaphragm 12D.

[0024]

On a downstream of the thermal medium tubes 11B, 11B, ... is formed a

combustion gas passage 11C through which the combustion gas after evaporating the raw fuel liquid through the thermal medium tubes 11B, 11B, ... is passed. The combustion gas passage 11C is arranged so as to surround a circumference of the evaporation chamber 11A, and is communicated with a superheating portion (not shown). The superheating portion is provided on a downstream of the evaporator body 11, and is formed in such a manner that the raw fuel gas evaporated in the evaporation chamber 11A is superheated by the combustion gas flowing via the combustion gas passage 11C.

[0025]

In addition, the raw fuel injecting apparatus 13 and the air introduction member 14 are disposed each on an upper portion of the evaporation chamber 11A of the evaporator body 11.

The raw fuel-injecting apparatus 13 possesses a plurality of, for example, three, raw fuel injecting portions 13A (nothing but one shown in Fig. 2), and the raw fuel liquid is injected from these raw fuel injecting portions 13A. The raw fuel injecting portion 13A is, for example, composed of an injector. By flowing a current to a solenoid coil (not shown) provided on the injector, a valve of the injector is designed to be opened so as to inject the raw fuel liquid from a nozzle thereof. Based on a signal for injecting the raw fuel liquid from the control unit CU shown in Fig. 1, the current is supplied to the solenoid coil or breaks down to open or close the valve.

[0026]

Furthermore, the air introduction member 14 comprises a number of air introduction ports 14A (nothing but one shown in Fig. 2), for example, three air introduction members of the present invention, which corresponds to the number of the raw fuel injecting portions 13A, are provided. The air as the

reforming air is supplied from the air compressor 5 to respective air introduction ports 14A, and is supplied to the evaporation chamber 11A of the evaporator body 11. Together with and well mixed with the raw fuel gas obtained by evaporating the raw fuel liquid, the air as the reforming air is supplied to the reformer 3. The reforming air is brought into contact with the reforming catalyst within the reformer 3 to promote reforming reaction of the raw fuel gas.

[0027]

In addition, each of the air introduction ports 14A is provided so as to reside adjacent to each of the raw fuel injection portions 13A of the raw fuel-injecting apparatus 13. The air introduced from the air introduction ports 14A is introduced toward a prescribed direction into the evaporation chamber 11A of the evaporator body 11. The air generates an air current, which has an effect of dispersing the raw fuel liquid injected from the raw fuel injecting portions 13A, while dividing the raw fuel liquid into fine droplets. Furthermore, the air introduction ports 14A are configured so that the injection direction of the raw fuel liquid can be set by the generated air current.

[0028]

The air introduction member 14 has also possesses a port 14B for introducing the air for starting (hereinafter referred to as "starting air introduction port 14B), which is a second air introduction member according to the present invention. Both the air introduction ports 14A and the starting air introduction port 14B in the air introduction member 14 are connected to the air compressor 5 shown in Fig. 1. In addition, as shown in Fig. 1, a first control valve 7A is provided on a conduit 8A between the air introduction ports

14A and the air compressor 5, and a second control valve 7B is provided on a conduit 8B between the starting air introduction port 14B and the air compressor 5. Both the first control valve 7A and the second control valve 7B are connected to the control unit CU and are controlled. Furthermore, the starting air introduction port 14B has a diameter larger than that of the air introduction ports 14A. For this reason, a large amount of the air can be introduced from the starting air introduction port 14B in comparison with the air introduction ports 14A.

[0029]

The reformer 3 has a plurality of reforming catalysts, and allows the raw fuel gas obtained by evaporating the raw fuel liquid in the evaporator for coming into contact with the reforming catalyst to thereby produce fuel gas with a high hydrogen content by the reforming reaction. The reforming air used in the course of the reforming reaction in the reformer 3 is supplied from the evaporator 2 together with the raw fuel gas. The combustion gas obtained by the reforming reaction in the reformer 3 is then supplied to the CO remover 4.

[0030]

In the CO remover 4, carbon monoxide contained in the fuel gas transferred from the reformer 3 is removed by reaction between carbon monoxide and oxygen in the present of a selective oxidation catalyst to be selectively oxidized into carbon dioxide. The fuel gas from which the harmful substance is removed is exhausted from the CO remover 4 and is supplied to the anode side of the fuel cell 1.

[0031]

In addition, the air compressor 5 inhales the air, that is, outside air, and

supplies it to the cathode side of the fuel cell 1. Furthermore, the air compressor 5 supplies the air as the reforming air to the air introduction member 14 provided on the evaporator 2. In addition, the air compressor 5 supplies the air as CO removal air for removing the carbon monoxide, which is harmful to the fuel cell 1, to the CO remover 4.

[0032]

Futhermore, the off gas, which is the exhaust gas, is exhausted from the fuel cell 1. The off gas is exhaust both from the anode side and the cathode side of the fuel cell 1. From the anode side, the fuel gas remaining unused in the reaction is exhaust as anode side off gas. Also, from the cathode side of the fuel cell 1, the air having not been used in the reaction is exhausted as the cathode side off gas. Both the anode side off gas exhausted from the anode side of the fuel cell 1 and the cathode side off gas exhausted from the cathode side are supplied to the catalytic combustor 12 in the evaporator 2. In the catalytic combustor 12 is combusted the anode side off gas as a fuel with making the cathode side off gas an oxidant gas, and thus heat is obtained.

[0033]

The starting combustion burner 6 is used at the time of starting the fuel cell system FCS and at the time when no off gas has yet been produced from the fuel cell 1. From the starting combustion burner 6, methanol fuel and the like are supplied to the catalytic combustor 12. Subsequently, the fuel is designed to be catalytically combusted on the catalyst layer 12B (see Fig. 2) over the catalytic combustor 12 to increase a temperature of the catalyst layer 12B in a short period of time.

[0034]

On a conduit 8C through which gas (hereinafter referred to as "mixed

gas") comprising the raw fuel gas exhausted from the evaporator 2 mixed with the reforming air flows is provided a first thermometer T1. The first thermometer T1 measures a temperature of the air exhausted from the evaporator 2 at the time of starting the fuel cell system FCS. Because the air exhausted from the evaporator 2 is increased or decreased corresponding to a temperature of the evaporator 2, the temperature of the air exhausted from the evaporator 2 can be deduced as that of the evaporator 2. Then, a signal for the temperature of the evaporator 2 based on a temperature of the mixed gas measured by the first thermometer T1, in other words, based on the temperature of the evaporator 2, is outputted from the first thermometer T1 to the control unit CU.

[0035]

In addition, a second thermometer T2 comprising any of a thermocouple and a thermister is attached to the reforming catalyst in the reformer 3 and measures a temperature of the reforming catalyst. A reforming catalyst temperature signal, which is based on the reforming catalyst, measured by the second thermometer T2 is outputted from the second thermometer T2 to the control unit CU.

[0036]

The control unit CU having an ECU (Electronic Control Unit) and the like performs various computation processings. To the control unit CU are outputted the evaporator temperature signal based on the temperature of the evaporator 2 measured by the first thermometer and the reforming catalyst temperature signal based on the temperature of the reforming catalyst measured by the second thermometer. The control unit CU calculates an amount of the raw fuel liquid to be injected, an amount of the air to be

introduced into the evaporator 2, and the like; based on these temperature signals, an output request from the fuel cell 1, and the like. Various signals based on the calculation values are outputted to the raw fuel injecting portions 13A in the raw fuel-injecting apparatus 13, the air introduction ports 14A in the air introduction member 14, the control valves 7A and 7B, and the like.

[0037]

An operation of the fuel cell system FCS thus having the configuration will be described, referring to Figs. 1 and 2.

First, the operation of the fuel cell system FCS at the time of starting will be described.

At the time of starting the fuel cell system FCS, the evaporator 2 is cool, and the temperature of the reforming catalyst in the reformer 3 is also low. For this reason, the evaporator 2 is requested to be warmed up and the temperature of the reforming catalyst in the reformer 3 is requested to be increased. First, in order to warm up the evaporator 2, the methanol fuel and the like are combusted in the starting combustion burner 6 to generate a high temperature gas, which is transferred into the thermal medium tubes 11B, 11B, ... of the evaporator 2. At this time, the air supplied from the air compressor 5 is introduced from the starting air introduction port 14B into the thermal medium tubes 11B, 11B, ... by a relatively large amount. Because the air supplied into the evaporation chamber 11A of the evaporator body 11 serves as the thermal medium, which takes away heat from the thermal medium tubes 11B, 11B, ... having been heated by the high temperature gas, and spreads the heat over a whole of the evaporator body 11, the evaporator 2 can be rapidly warmed up. Here, temperature changes in cases where the air is introduced into the evaporator 2 and no air is introduced into the evaporator

2 are shown in Fig. 3. As is proven from Fig. 3, when the air is introduced in the evaporator 2, the temperature of the evaporator 2 is rapidly increased, while an increase of the temperature of the evaporator 2 is delayed in the case where no air is introduced into the evaporator 2. As described above, the introduction of the air into the evaporator 2 allows for rapidly warming up the evaporator 2.

[0038]

In addition, in order to rapidly warm up the evaporator 2, a certain degree of an air amount is required. Fig. 4 shows a relationship between an amount of the air introduced from the starting air introduction port 14B (hereinafter referred to as "starting air amount") and a period until the evaporator 2 can be started (hereinafter referred to as " evaporator starting period"). As it turns out from Fig. 4, if the starting air amount is small, the evaporator starting period becomes slow. There is a tendency that the evaporator starting period becomes faster as the starting air amount increases. For this reason, a large amount of the air is introduced at the time of starting the fuel cell system FCS.

[0039]

Thus, the air having been used as the thermal medium to rapidly warm up the evaporator 2 becomes an evaporator exhaust air as it is, is exhausted from the evaporator 2, is transferred into the reformer 3, and in the reformer 3, the reforming catalyst is heated up by the evaporator exhaust air. For this reason, without using any starting combustion burner for heating up the reforming catalyst of the reformer 3, the temperature of the reforming catalyst of the reformer 3 can be increased. And when any temperature of the evaporator 2 and the temperature of the reforming catalyst of the reformer 3

becomes a prescribed temperature or more, the warming-up of the fuel cell system FCS is judged to be completed, and then the raw fuel gas is introduced.

[0040]

In the normal operation of the fuel cell system FCS other than the time for starting the fuel cell system FCS, raw fuel liquid such as water/methanol mixed liquid is supplied from the tank T to the raw fuel-injecting apparatus 13 in the evaporator 2. When the raw fuel liquid is injected, the air is introduced through the air introduction ports 14A in the air introduction member 14 into the evaporation chamber 11A of the evaporator body 11 in the evaporator 2. A flow amount of the air introduced from the air introduction ports 14A varies with matching an amount of the fuel gas, which varies depending on a load request to the fuel cell 1 and the like. In order to deal with a case of a small variation amount, the flow amount of the air to be introduced from the air introduction ports 14A cannot be too much. For this reason, in order to introduce a large amount of the air at the time of the starting, the starting air introduction port 14B is separately provided. By providing the air introduction ports 14A and the starting air introduction port 14B separately, thus structures for obtaining a finely controlled flow amount of air and introducing a large amount of air are made separately, and thereby there is an advantage that the structures can be made simpler than individual structures are unified into one.

[0041]

As described above, the air introduced from the air introduction ports 14A generates an air current. In addition, an appropriate amount of the raw fuel liquid is injected from the raw fuel injection portions 13A of the raw fuel-injecting apparatus 13. At this time, the raw fuel liquid injected from the

raw fuel injection portions 13A is finely divided into small droplets by means of the air current occurring in the course of an introduction of the air from the air introduction ports 14A, and dispersed into the evaporation chamber 11A. The raw fuel liquid dispersed into the evaporation chamber 11A is uniformly sprayed onto whole outer surfaces of the thermal medium tubes 11B, 11B, ... through which the off gas flows, to be thereby efficiently evaporated to give the raw fuel gas.

[0042]

The raw fuel gas obtained in the evaporation chamber 11A is supplied from the evaporator 2 to the reformer 3. At this time, the reforming air introduced together with the raw fuel gas is also supplied from the evaporator 2 to the reformer 3. In the reforming air introduced into the evaporator 2 becomes long a period of time (distance) when the reforming air in such a piping from an inside of the evaporator chamber 11A in the evaporator 2 to that of the reformer 3 is mixed with the raw fuel gas. For this reason, because the reforming air is well mixed with the raw fuel gas, a mixture of the raw fuel gas with the reforming air becomes a state suitable for the reformation.

[0043]

Here, a temperature difference between a case as a present invention example where the reforming air is introduced into the evaporator 2 and another case as a conventional example where no reforming air is introduced into the evaporator 2 will be compared. Fig. 5 is a graph showing the difference between a maximum surface temperature of the reforming catalyst and a minimum surface temperature thereof (hereinafter referred to as "in-surface temperature difference") in the present invention example and the

conventional example. As is clear from Fig. 5, the in-surface temperature difference in the conventional example is approximately four times of that in the present invention example. Thus, the present invention example can suppress the in-surface temperature difference to a low level. Consequently, because the present invention example can prevent a generation of uneven temperature of the surface of the reforming catalyst in the reformer 3, it can suppress a generation of unreformed gas (increase of THC) and an increase of the CO concentration.

[0044]

Next, operation procedures of starting the fuel cell system according to the present invention will be described, referring to a flowchart shown in Fig. 6.

When the fuel cell system FCS is started (SS), a methanol based fuel an the like are supplied from the starting combustion burner 6 to the catalyst layer 12B of the evaporator 2. At the same time, the control unit CU outputs a closing signal to the first control valve 7A and an opening signal to the second control valve 7B (S1). Consequently, the air from the air compressor 5 is not supplied to the air introduction ports 14A, but supplied to the starting air introduction port 14B. The air supplied to the starting air introduction port 14B is then introduced into the evaporation chamber 11A of the evaporator body 11 (S2). At this time, the raw fuel liquid has not yet been injected from the raw fuel-injecting apparatus 13.

[0045]

A large amount of the air has been introduced into the evaporation chamber 11A from the starting air introduction port 14B. For this reason, the catalyst combustor 12 can warm up the whole of the evaporator 2 at an early

stage. Thus, the air introduced into the evaporator 3 has been utilized for the warming-up of the evaporator 2 as the thermal medium, and then, the air is exhausted from the evaporator 2 into the reformer 3 and is used as a heat source for increasing the temperature of the reforming catalyst. At this time a temperature Tv of the exhaust air from the evaporator 2 in the conduit 8C through which the exhaust air is passed in the course of a supply into the reformer 3 is measured by the first thermometer T1 (S3). The temperature Tv of the evaporator exhaust air measured by the first thermometer T1 is outputted to the control unit CU in which it is dealt as the evaporator temperature signal. On the other hand, a temperature Tr of the reforming catalyst in the reformer 3 is measured by the second thermometer T2 provided on the reforming catalyst of the reformer 3 (S4). The temperature Tr of the reforming catalyst measured by the second thermometer T1 is outputted to the control unit CU in which it is dealt as the reforming catalyst temperature signal.

[0046]

The control unit CU judges whether or not the temperature Tv of the evaporator exhaust air exceeds a prescribed threshold value Tvs (S5). Also, at the same time the control unit CU judges whether or not the temperature Tr of the reforming catalyst exceeds a prescribed threshold value Trs. The threshold value Tvs and the threshold value Tvr can be appropriately set. For example, the threshold value Tvs of the temperature Tv of the evaporator exhaust air can be made a temperature where the raw fuel liquid within the evaporator 2 becomes able to be sufficiently evaporated. Also, the threshold value Trs of the temperature Tr of the reforming catalyst can be made a temperature where the reforming reaction becomes able to be sufficiently

carried out.

[0047]

If the temperature Tv of the evaporator exhaust air does not exceed the threshold value Tvs and the temperature Tr of the threshold value Tvr as a result of the step S5, the step is returned to the step S3. Then, the temperature Tv of the evaporator exhaust air is measured by the first thermometer T1 and the temperature Tr of the reforming catalyst is measured by the second thermometer T2. On the other hand, if the temperature Tv of the evaporator exhaust air exceeds the prescribed threshold value Tvs or the temperature Tr of the reforming catalyst exceeds the prescribed threshold value Trs, the control unit CU judges that the fuel cell system FCS has been ready for carrying out the reforming reaction and outputs an injection signal to the raw fuel-injecting apparatus 13.

[0048]

The raw fuel-injecting apparatus 13 which has received the injection signal starts an injection of the raw fuel liquid from the raw fuel injection portions 13A towards the evaporation chamber 11A (S6). Together with outputting the injection signal for the raw fuel injection portions 13A, the control unit CU outputs an opening signal to the first control valve 7A and a closing signal to the second control valve 7B. Upon receiving the opening signal from the control unit CU, the first control valve 7A is opened, and the second control valve 7B, to which the closing signal is outputted, is closed (S7). By opening the first valve 7A, the air is introduced from the air introduction ports 14A into the evaporation chamber 11A in the evaporator body 11. Due to the closing of the second control valve 7B, the introduction of the air from the starting air introduction port 14B is stopped (S8). The air introduction

ports 14A, which introduces the air into the evaporation chamber 11A not by a large amount, generates an air current by introducing the air. Each of the air introduction portions 14A is placed adjacent to each of the raw fuel injection portions 13A, and the raw fuel liquid injected from each of the raw fuel injection portions 14A is dispersed while it is divided into fine droplets by the current generated by introducing the air. The finely divided, dispersed raw fuel liquid uniformly comes into contact with the thermal tubes 11B, 11B, ... placed within the evaporation chamber 11A and, therefore, the evaporation of the raw fuel liquid is promoted. Moreover, an air amount introduced depending on an injection amount of the raw fuel liquid, which is injected in the evaporation chamber 11A, can be meticulously adjusted.

[0049]

The air introduced from the air introduction ports 14A is supplied from the evaporator 2 to the reformer 3 together with the raw fuel gas formed by an evaporation of the raw fuel liquid. The reformer 3 produces a hydrogen-enriched fuel gas by bringing the raw fuel gas into contact with the reforming catalyst to carry out the reforming reaction. While the reforming air is required in the reforming reaction, the air supplied from the evaporator 2 together with the raw fuel gas serves as the reforming air in the reformer 3. The reforming air to be supplied to the reformer 3 has been thoroughly mixed with the raw fuel gas in the course of being supplied from the evaporator 2 to the reformer 3. Accordingly, the in-surface temperature difference becomes small, and the generation of the unreformed gas and the increase of the CO concentration can be suppressed.

[0050]

Thus, after the introduction of the air from the air introduction ports

14A is started and the air introduction from the starting air introduction port 14B is stopped, the introduction of the air for removing CO into the CO remover 4 is started (S9). Thus, the starting of the fuel cell system FCS is ended (SE). When the starting of the fuel cell system FCS is ended, a full-fledged operation of the fuel cell system FCS is started. Even after the full-fledged operation of the fuel cell system FCS is started, the mixed gas having the reforming air mixed with the raw fuel gas is still supplied from the evaporator 2 to the reformer 3. For this reason, the in-surface temperature difference of the reforming catalyst can be suppressed to a low level, and thus, the generation of the unreformed gas and the increase of the CO concentration can be suppressed.

[0051]

Next, the second embodiment of the present invention will be described.

The embodiment is as that of the first embodiment except that the starting air introduction port 14B and accompanying parts such as the conduit 8B and the second control valve 7B are not provided.

[0052]

In the fuel cell system FCS according to the embodiment, the operation procedures at the time of starting the fuel cell system FCS are different, compared to those of the fuel cell system FCS according to the first embodiment. The operation procedures at the time of starting the fuel cell system FCS according to the embodiment, mainly focusing on the procedures different from those of the first embodiment, will be described.

When the fuel cell system according to the embodiment is started, in the first embodiment the methanol based fuel and the like are supplied from the starting combustion burner to the catalytic combustor 12, and then air is

introduced from the air introduction ports 14B into the evaporation chamber 11A; while in the second embodiment the air is introduced from the starting air introduction ports 14A into the evaporation chamber 11A. Subsequently, same as in the case of the first embodiment, the temperature Tv of the evaporator exhaust air is measured by the first thermometer T1, and the temperature Tr of the reforming catalyst is measured by the second thermometer T2. And when the temperature Tv of the evaporator exhaust air exceeds the prescribed threshold value Tvs or the temperature Tr of the reforming catalyst exceeds the prescribed threshold value Trs, the first control valve 7A comes to a close to thereby stop the air introduction. Subsequently, the injection of the raw fuel liquid from the raw fuel-injecting apparatus 13 is started, and at the same time the first control valve 7A is opened to start the air introduction from the air introduction ports 14A. Thereafter, the air for removing CO is introduced into the CO remover 4, the starting of the fuel cell system is stopped, and then full-fledged operation of the fuel cell system is started.

[0053]

Compared to the first embodiment, because in the second embodiment the fuel cell system requires no starting air introduction port, the whole of the apparatus can be realized to be miniature.

[0054]

While the preferred embodiments of the present invention have been described, the present invention should not be restricted to such the embodiments. For example, the starting air introduction port 14B has a diameter larger than that of the air introduction ports 14A in the embodiments, the diameter of the starting air introduction port 14B can be substantially

same as that of the air introduction ports 14A and smaller than that of the air introduction ports 14A. In such cases, for example, in order to be able to introduce a large amount of the air into the evaporator 2 at the time of starting the fuel cell system, the air can also be introduced into the evaporator 2 both from the air introduction port and the starting air introduction port. Of course, it is applicable that in the step for introducing the air from the starting air introduction port 14B according to the first embodiment, the air is designed to be introduced also from the air introduction member 14.

[0055]

In addition, while the air introduced from the air introduction ports 14A generates an air current, are also preferable such embodiments as generating any of a swirl current, a zigzag current, and a deflected current in order to preferably make the raw fuel fine droplets and disperse them.

[0056]

Moreover, in the embodiments, although when the injection (supply) of the raw fuel liquid is started, any of the temperature of the evaporator and the temperature of the reforming catalyst exceeds a prescribed threshold value, another embodiment is also available where the injection (supply) of the raw fuel liquid is started after both of the temperature of the evaporator and the temperature of the reforming catalyst exceed respective threshold values.

[0057]

[Effects of the Invention]

Thus, according to an invention of claim 1 out of the present invention, it can be made to adequately mix fuel gas with reforming air in a reformer and operate an evaporator and the reformer at the time of starting without making a fuel cell system large as a whole.

[0058]

According to an invention of claim 2, it can be made to supply a large amount of air to an evaporator at the time of starting and preferably introduce an amount of air, which matches an injection amount of a liquid raw fuel, to the evaporator at the time of a normal operation.

[0059]

According to an invention of claim 3, it can be made to make it simple a structure of the air introduction member and the second air introduction member and make control easy by introducing reforming air from the air introduction member at the time of a normal operation.

[0060]

According to inventions of claims 4 and 5, it can be made to supply liquid raw fuel to an evaporator and surely start production of fuel gas, after a state where fuel can be reformed in a fuel cell system becomes ready.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 shows a configuration of a fuel cell system according to the present invention.

[Fig. 2]

Fig. 2 is a side cross-sectional view showing an example of an evaporator.

[Fig. 3]

Fig. 3 is a graph showing a temperature change in a case of introduction of air into an evaporator and another temperature change in a case of no introduction of the air into the evaporator.

[Fig. 4]

Fig. 4 is a graph showing a relationship between an amount of air introduced at the time of starting a fuel cell system and a period for starting an evaporator.

[Fig. 5]

Fig. 5 is a graph showing differences in a surface of a reforming catalyst in a prior art example and a present invention example.

[Fig. 6]

Fig. 6 is a flowchart showing operation procedures for starting a fuel cell system according to the present invention.

[Fig. 7]

Fig. 7 shows a configuration of a conventional fuel cell system.

[Fig. 8]

Fig. 8 is a graph showing a relationship between a concentration of carbon monoxide in fuel gas and a temperature of a reforming catalyst.

[Description of Reference Alpha-Numerals]

1: Fuel cell

2: Evaporator

3: Reformer

4: CO Remover

5: Air Compressor

6: Starting Combustion Burner

11: Evaporator Body

12: Catalyst Combustor

13: Raw Fuel Injector

13A: Raw Fuel Injection Portion

14: Air Introduction Member

14A: Air Introduction Port (Air Introduction Member (Means))

14B: Starting Air Introduction Port (Second Air Introduction Member (Means))

FCS: Fuel Cell System

CU: Control Unit

T1: First Thermometer

T2: Second Thermometer

Tv: Temperature of Evaporator Exhaust Air (Evaporator Temperature Signal)

Tr: Temperature of Reforming Catalyst (Reforming Catalyst Temperature Signal)

[Name of Document] Abstract

[Abstract]

[Problems] It can be made to adequately mix fuel gas with reforming air in a reformer and operate an evaporator and the reformer at the time of starting without making a fuel cell system large as a whole.

[Means for Solving the Problems] Air for reforming used in a reforming reaction in a reformer 3 of a fuel cell system FCS is supplied to an evaporator 2. In the evaporator 2, raw fuel liquid is evaporated to produce raw fuel gas. The reforming air and the raw fuel gas are well mixed within the evaporator 2 and a conduit 8C where the raw fuel gas is supplied from the evaporator 2 to the reformer 3. In addition, at the time of starting the fuel cell system FCS, a large amount of air is introduced into the evaporator 2 via an air inlet port 14B.

[Figures to be Selected] Fig.1